Renewable and Sustainable Energy Reviews 95 (2018) 203–216

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The economic effects of renewable energy expansion in the electricity sector: A CGE analysis for Malaysia

Fatemeh Chatri[a,*], Masoud Yahoo[b], Jamal Othman[a]

[a] School of Economics, Faculty of Economics and Management, National University of Malaysia, 43600 Bangi, Malaysia
[b] Faculty of Economics, Kharazmi University, No. 43, Taleghani Ave., Tehran, Iran

ARTICLE INFO

Keywords:
CO_2 Emissions
Electricity
Subsidy removals
CGE modeling
Renewable energy
Malaysia

ABSTRACT

Electricity is a critical factor in developing a robust and modern economy and for improving the quality of life. In Malaysia, the electricity sector benefits from heavy subsidies to its gas inputs. Such economic interventions disrupt price mechanisms and result in inefficient resource allocations, over-consumption of electricity, CO_2 emissions, and government budget deficits. Under the Tenth Malaysia Plan price controls and subsidies have been rationalized to achieve complete market pricing. In addition, in consideration of climate change issues, environmental concerns, and strengthening energy supply security through diversification, the government encourages the use of renewable energy for electricity production through the Feed-in-Tariff (FiT) strategy. This study employs a Computable General Equilibrium (CGE) model to examine the potential impacts of gas subsidy reform in the power sector and on the Malaysian economy. The model evaluates and compares the impacts of two methods of providing funds for encouraging the development of renewable energy production, reallocating revenues from gas subsidy removal, and remunerating the FiT mechanism. The simulation results show that reducing gas subsidies without recycling the revenues gained decreases electricity demand and emissions significantly while having only minimal negative effects on macroeconomic variables. The results indicate that utilizing a recycling plan in which additional revenues from subsidy reforms are re-allocated to finance the FiT framework contributes significantly to the production of renewable energies within the power generation sector in Malaysia.

1. Introduction

Energy is a key factor that powers the economy and promotes the sustainable development of countries. The challenge of continuously generating electricity and coping with rising demand exerts enormous pressure on the energy infrastructures of both developed and developing countries. As such, governments maintain or control electricity and transport fuel prices at very low levels, especially through the provision of input subsidies or cash transfers to offset the production costs of energy producers [1].

As a developing country seeking to maintain its economic growth and promote development, Malaysia relies heavily on fossil fuels namely coal, natural gas, and oil to meet the energy demands of power producers and final commercial energy consumers. Fuel subsidies in the power sector are mainly provided for gas and oil rather than coal. Although oil-based energy generation is subsidized, the amounts are not as much as directed to the transportation and other (direct) usage sectors as its share in power generation in Malaysia is relatively small [2].

A study by Birol [3] shows that Malaysia's expenditure of US$5.7 billion on subsidies for the energy sector was the third-highest among the ASEAN-5 nations in 2010 and 2016 compared to the US$15.9 billion for Indonesia and US$8.5 billion for Thailand. Subsidies for the electricity sector accounted for nearly US$0.8 billion (see Fig. 1 for more details).[1]

The Malaysian power sector has long been reliant on gas which, on average, accounted for two-thirds of its generation, specifically after 1995. After a series of major investments in coal-fired power stations (1994), Malaysian energy policy shifted its focus back to gas which currently accounts for more than half of its generation until now.

* Corresponding author.
E-mail address: f.chatri89@gmail.com (F. Chatri).

[1] It should be noted that the mentioned direct subsidy on electricity prices is not the focus of this study although we have noted them as part of the discussion. The focus of this study is to simulate the impacts of a consumption subsidy specific to the fossil fuels consumed by electricity producers (input) and not the electricity commodity itself (final demand).

https://doi.org/10.1016/j.rser.2018.07.022
Received 19 October 2017; Received in revised form 24 June 2018; Accepted 13 July 2018
Available online 27 July 2018
1364-0321/

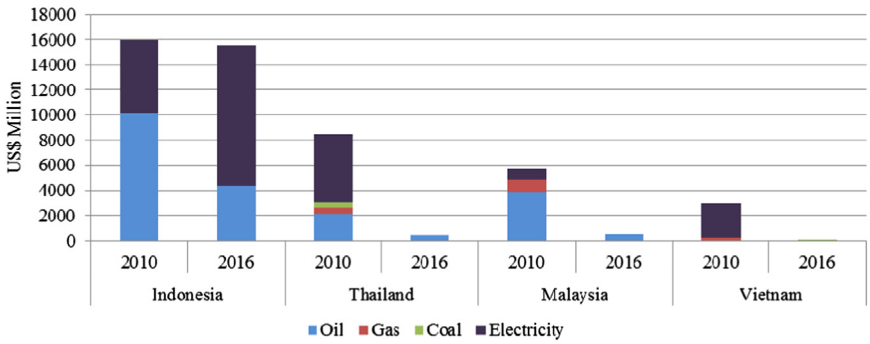

Fig. 1. Energy subsidies for selected ASEAN countries, (2010, 2016).
Source: International Energy Agency [4,5].

Therefore, gas-based generation capacity continues to be built at a rate that has barely kept pace with the domestic supply capacity of PETRONAS.[2] As shown in PETRONAS imports 36% of Malaysia's natural gas which is then supplied to Tenaga Nasional Berhad (TNB) at approximately 25% of the imported cost price and nearly half of what it costs in neighboring Singapore [2]. In 2010, the Malaysian Energy Commission embarked on gradually removing the subsidy on gas prices which increased from MYR10.70 ($3.32) per MMBtu to per MYR22 ($6.83) MMBtu by 2015 [2]. In 2015, the natural gas prices of power producers was capped at MYR15.2 ($3.90) per MMBtu compared to the market rate of around MYR46.04 ($11.8) per MMBtu [7], thus benefiting electricity producers with a 67% discount on the purchased gas price. As such, Malaysian power generators enjoy one of the cheapest gas prices in the region, behind Brunei and Indonesia [2].

Fig. 2, due to the sharp increase in world oil prices and to balance the ratio of the fuel-mix, especially since Malaysia is blessed with abundant natural gas reserves, natural gas usage has increased substantially from less than 5% in 1978 to as high as 41% in 2015.

PETRONAS imports 36% of Malaysia's natural gas which is then supplied to Tenaga Nasional Berhad (TNB) [3] at approximately 25% of the imported cost price and nearly half of what it costs in neighboring Singapore [2]. In 2010,[4] the Malaysian Energy Commission embarked on gradually removing the subsidy on gas prices which increased from MYR10.70 ($3.32) [5] per MMBtu[6] to per MYR22 ($6.83) MMBtu by 2015 [2]. In 2015, the natural gas price of power producers was capped at MYR15.2 ($3.90) per MMBtu compared to the market rate of around MYR46.04 ($11.8) per MMBtu [7], thus benefiting electricity producers with a 67% discount on the purchased gas price. As such, Malaysian power generators enjoy one of the cheapest gas prices in the region, behind Brunei and Indonesia [2].

At the same time, the growing size of the gas subsidy due to the increase in electricity consumption imposes a heavy burden on the government's budget. Since 1997, PETRONAS lost an estimated MYR238.3 ($61.1) billion in foregone revenues by subsidizing gas used by the power and non-power sectors [8]. The total value of the gas subsidy reached MYR10.9 ($2.79) billion in 2015 representing a major increase of 47.3% since 2005. Of that amount, 49.5% or MYR5.4 ($1.38) billion was for the non-power sector which includes industries,

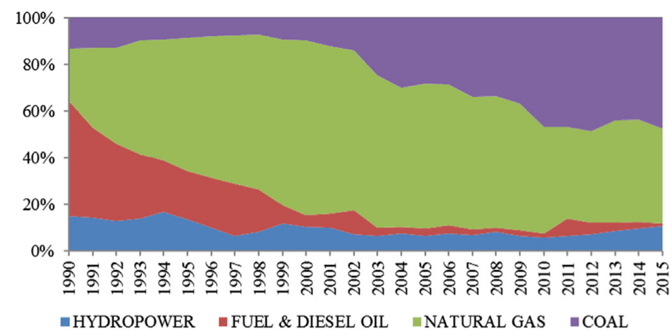

Fig. 2. Electricity generation fuel mix, Malaysia (1990–2015).
Source: author's based on [6].

and commercial and residential users, with the balance 50.5% (MYR5.5 ($1.41) billion) going for power generation. The government continues to subsidize gas by as much as 71–77%, which means lost opportunities for the country and a less than cost-efficient economy. Table 1 shows the natural gas subsidies provided to the power sector.

Although subsidies can generate social benefits in terms of improving the income distribution for low income households, the other key policy issues involved regarding the electricity sector in Malaysia are firstly, providing natural gas at a lower price to electricity producers translates into the supply of electricity with prices below actual price to the final consumers which in turn increased electricity consumption. Secondly, from a budgetary point of view, these subsidies are costly for the government since any increase in natural gas market prices would require greater budget allocations to cover the gap between domestic and market sale prices. Thirdly, in terms of the environment, while subsidized natural gas inputs have contributed to keeping emissions down, the lower prices for end-users results in increased consumption.[7] According to [9], about 47% of total CO_2 emissions from fuel combustion is produced by the power generation sector in Malaysia. Therefore, electricity generation is the largest emitting factor and its higher consumption leads to greater greenhouse-gas emissions. Fourthly, 53% of the Malaysia's total energy mix is attributed to natural gas, while gas reserves are projected to last another 32 years[8][10]. This will have implications for sustainability and energy security when the switch to alternative energy solutions such as renewable energy (RE) occurs in the fuel-mix [11]. Further, a cut in the natural gas subsidy can be used to improve productivity in the power generation sector in

[2] Malaysia's state-owned national oil company Petroleum Nasional Berhad (PETRONAS).

[3] Malaysia's National Power Corporation.

[4] Since the benchmark data used in the paper is the latest input output tables for 2010 (published in 2015) and due to the linkages between database and the real economic situation, the data presented here refers to 2010.

[5] Based on data from the International Monetary Fund (International Financial Statistics), 1 $ equals 3.221 Malaysian Ringgit or MYR (Malaysia's currency unit) in 2010.

[6] Million metric British Thermal Units or MMBtu (natural gas unit of measurement).

[7] This point is different from first one, since this mentions environmental concerns. In other words, by providing natural gas with subsidized price, contributes to keeping emissions down while an increase in electricity will increase emissions.

[8] Malaysia's natural gas reserves and production in 2010 were 88.587 (Tscf) and 2.7 (Tscf) respectively.

Table 1
Natural gas price and its subsidy, Malaysia (2005–2015).
Source: author's based on [7,8]

Year	Total Subsidy (RM bill)		Subsidized price (MYR/MMBTU)
	TNB	IPP[a]	
2005	2.3	3.9	6.4
2006	5	6.5	6.4
2007	5	6.7	6.4
2008	5.7	8.1	14.31
2009	5.4	7.3	10.70
2010	5	6.2	10.70
2011	4.9	6.7	13.7
2012	6.1	9.5	13.7
2013	5.3	8.4	13.7
2014		12.4[b]	15.20
2015		5.5	15.2

[a] Independent Power Producers.
[b] Sum of TNB and IPP together.

particular, and improve overall economic productivity within the energy sector.

Any removal of the gas subsidy will lead the power sector to substitute coal because of its comparatively lower cost. As coal is a polluting fossil fuel, it is important that credible alternatives to coal are available before removing the subsidies to avoid intensification in total CO_2 emissions from the power sector [12]. On the other hand, transferring the higher costs of electricity production to the final consumer through the FiT mechanism is by itself not effective enough to promote the utilization of RE sources in the electricity sector [13]. As a policy option, a revenue recycling plan should allow renewable energy initiatives within the power generation sector to be financed through revenues generated from reforms to the gas subsidy via a FiT scheme. Since electricity is the second highest commercial type of energy used by final demanders[9][10], any energy subsidy policy reforms will have a significant impact on the Malaysian economy. Currently, no credible quantitative model exists to evaluate the economy wide-effects of a gas subsidy removal policy and the reallocation of revenue through a FiT mechanism. This study seeks to fill that gap by employing a computable general equilibrium model that takes into account the specific characteristics of the electricity sector in Malaysia.

Energy subsidy reform and RE production development policies will significantly affect the electricity sector as well as the Malaysian economy. The main objective of this paper is to provide a quantitative analysis of alternative scenarios in Malaysia's power sector using a static Computable General Equilibrium (CGE) model with electricity-economy interactions. Specifically, it:

i) analyzes the impact of a reduction in gas-based electricity subsidies with and without a recycling plan on major economic indicators in Malaysia such as GDP, government expenditure, industrial output, prices, and welfare;
ii) estimates the economic effects of reallocating gas subsidies to broaden the use of RE in electricity generation through the FiT mechanism.

The rest of this paper is organized as follows: Section 2 reviews the literature on energy subsidy reforms, Section 3 discusses the components of the methodology such as model description, database, and scenario design, Section 4 presents the simulation results and discussions, and Section 5 concludes the paper and provides the policy implications.

[9] Total final use of motor petrol and electricity were 9560 ktoe and 8993 ktoe respectively in 2010.

2. Literature review

Increasing world energy demand implies that the contribution from renewable energy will be a key source [14]. Therefore efforts to improve current technologies, create new generation fuels, and enhance different policies have been made by various countries. Feed-in-tariff (FiT) is a price-driven policy for promoting RE expansion which can be implemented by offering a guaranteed purchase price for electricity produced from RE sources [15]. Nevertheless, the expansion of various RE sources can be attained through different schemes [16]. These include raising the cost of electricity for developing solar PVs power plants [17] or a consumer-based FiT policy to reduce social costs and electricity generation [18]. Furthermore, [19] shows that a production-based FiT scheme that is not complemented with a motivated policy would not produce economically beneficial outcomes. Thus, a FiT mechanism supported by a subsidy policy would be an important issue that needs further research. The model that is applied in the paper to address the FiT mechanism involves an increase in prices which are complemented with a reduction in the natural gas subsidy in the Malaysian electricity industry. In line with [20] on the recycling scheme, the revenues saved from gas subsidy removal is channeled into the production of RE energies. This is necessary to return the full amount of the subsidy revenues to the economy in line with the revenue-neutrality assumptions [9].

Few studies have focused on the effects of various modes of electricity subsidies. Some estimate the amount of total subsidies in the electricity sector while others investigate the impact of subsidy reduction on the whole economy. In addition, literature on the impact of energy subsidy reform in electricity generation as a sub sector of the power sector is limited. Most of these studies employ econometric and analytical methods to achieve their objectives. Such a gap needs to be filled by including the effects of gas-based electricity subsidy reform on all the electricity generation sectors as well as an evaluation of offsetting policies on RE electricity production. This study thus uses the CGE framework which provides a robust method to comprehensively evaluate the effects of gas subsidy reform on the electricity sectors and the entire economy. However, studies using this method generally ignore substitution possibilities among electricity generation sectors and are confined mainly to the household sector. This study evaluates such offsets imposed on RE electricity as a production subsidy to promote clean energy alternatives and the protection of the environment.

The issue commonly addressed by the various studies is how economies are impacted by the removal or reduction of subsidies on the energy sector. Lin and Li [21] analyze a subsidy removal policy on China while the global outcomes are presented in the form of trade impacts. In comparing the CGE models used in different researches, it should be noted that they differ in regard to their research-specific objectives. For instance, in the Malaysian case Solaymani and Kari [22] analyzed the impacts of fuel subsidy removal in the transport sector. For Indonesia, the negative economy-wide and distributional effects of fuel subsidy reduction were studied by different researchers such as Yusuf et al. [23], Dartanto [24], and Oktaviani et al. [25]. AlShehabi [26] showed that in the absence of any recycling plan, the Iranian economy was negatively affected by the removal of the fuel subsidy in the transport sector. Alternatively, when the objective of the study is centered on the issue of production technologies across industries, an input-output based model which simplifies flows between households and government and other agents in the economy is sufficient to address the research objectives [27,28]. Based on a review of the literature, it can be concluded that when revenues from any subsidy removal are channeled to households, the resulting increase in demand will stimulate the economy, but when they are not injected into the economy or returned to sectors other than households, GDP growth will contract [23–25,27,29]. AlShehabi [26] showed that when the additional revenues are redistributed to the household sector, the labor and employment markets are adversely affected. From the emission

abatement perspective, Fuinhas, Marques et al. [30] and Paramati, Sinha et al. [31] showed that when more RE energies are produced, all sectors will be stimulated to achieve economic growth while contributing to a reduction in CO_2 emissions.

To date, there has been little empirical analysis on the impacts of an energy subsidy reform policy in the power generation sector using a comprehensive model involving detailed generation types for Malaysia. In other words, the models do not differentiate between the electricity and non-electricity sectors in terms of nested production and do not, for example, consider environmental benefits (in terms of CO_2 emissions from each type of power generators) of a subsidy reform policy. Further, since energy substitution is an important component of the subsidy removal policy, RE becomes a major player for which an important means of financing is through an appropriate FiT policy. This aspect is also not covered in the previous literature. Thus, this study fills these gaps by employing a single-country static CGE model together with an electricity-based extended input-output table using data from the Malaysian Department of Statistics [32] and National Energy balance [10]. The model uses explicit production substitution possibilities that also allow for the channeling of subsidy removal revenues towards promoting renewable energy production.

3. Methodology

Energy subsidy reform and development policies for RE production will have important effects on the electricity sector as well as on the overall Malaysian economy. To illustrate their potential economy-wide impacts and to estimate their magnitude, a market equilibrium model can be used in evaluating key aspects of a policy shift. For this study, a static CGE model of the Malaysian economy is applied with special emphasis on modeling the electricity sector with different interlinked activities related to substitutions between various fossil-fuels and renewable energies to generate the electricity.[10] Modeling the substitution between different energy sources in the electricity sector will prevent the overestimation of the economic burden of each subsidy removal and/or RE production development (FiT) policy on the overall economy. It should be noted that the core aspect of this CGE model is adopted from the standard ORANI-G model [33,34] and expanded to the Malaysia electricity general equilibrium model. Following Horridge [34], the basis for deriving the equations in the model of this study is linear in regard to the changes (percentage or absolute) in its variables. To clarify the relationships in the CGE model of paper, Fig. 3 shows the transaction flows between different factors in a schematic view.

3.1. Feature of the CGE model of Malaysia

3.1.1. Nested of production

In our model, the economy is disaggregated into 130 production sectors with each selected from a grouping of commodity classes in the 2010 input-output table. The input-output table has 124 industrial sectors and, in line with this research's objectives, some sectors are disaggregated and the economy is finally represented by 130 industries. The sectoral breakdown reflects the sub-sectors in the electricity and other major sectors of the economy as discussed in the database construction section. The grouping is designed for studying the interactions of the electricity, energy, and other sectors of the economy.

In line with an important feature of neoclassical microeconomic theory and following the Horridge [34] model, the optimization behavior in the model of this study is based on cost minimization where each industry minimizes its costs subject to a production technology. To accurately estimate the impacts of different policy shocks on the electricity sector following Adams et al. [35] model, this study distinguishes

[10] Appendix A presents the model description, parameters, and variables in greater detail.

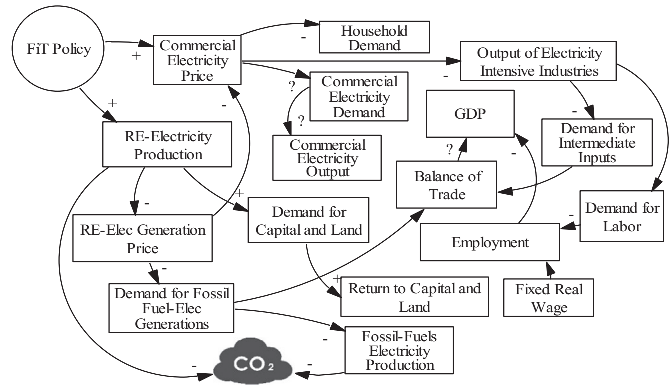

Fig. 3. Model flow diagram.

between the electricity supply industry and all other industries. It should be emphasized that in general there are 5 electricity-related sectors of which four are involved in electric generation and one in electricity supply. These distinctions are necessary when addressing actual electricity market issues for Malaysia.

The production input structure for all non-electricity supply industries follows the Horridge et al. [34] model.[11] The non-electricity producers are constrained in their choice of inputs by a three-level cost minimization process, and industries are assumed to choose a mix of inputs which minimizes the costs of production for their level of output when different Constant Elasticity of Substitution (CES) production technologies [29] [12] are assumed. At the first level, the input of labor is formed as a CES combination of labor inputs i.e., skilled and unskilled. At the second level, the intermediate input bundle is an Armington [37] and CES function that specifies imperfect substitutability between domestic and imported sources of commodities. At the third level, the intermediate-input and primary-factor composites, and other costs are combined in fixed proportions (Leontief function) to produce output.

3.1.2. Primary factor substitution

The composite labor, capital, and land inputs are aggregated to form a CES shaped primary-factor bundle. On the supply-side, the optimization problem is profit maximization when each industry assumes a two-stage profit maximization process to supply output in the market having a higher price. Before the source composite is selected at the final level, multi-product firms decide on the optimal mix of commodities to produce goods through a constant elasticity of transformation (CET) function. Then, in the top, another CET transformation function is employed to separate the supply of goods between domestic and export markets.

3.1.3. Energy substitution

Technological information is especially relevant in the electricity sector and is critical in analyzing the effects of subsidy reduction because of the existence of a wide range of generation technologies. Accordingly, this study modified the Horridge [34] model by extending the production structure for the electricity generation composite to allow for substitution possibilities among four types of electricity generation instead of placing electricity generation in the Leontief functional form at the same level of the other industries. Electricity

[11] ORANI-G is a generic version of the well-known ORANI CGE model of Australia. See Horridge [24] for a detailed description of the model and database as developed for Australia.

[12] CES functions are a general production function form that depicts substitution between capital and labor and shows cases between a Leontief and a Cobb-Douglas function. In mathematic form, a CES function describes the amount of change required in one input in response to a certain amount of change in other input(s) subject to a given production level [36].

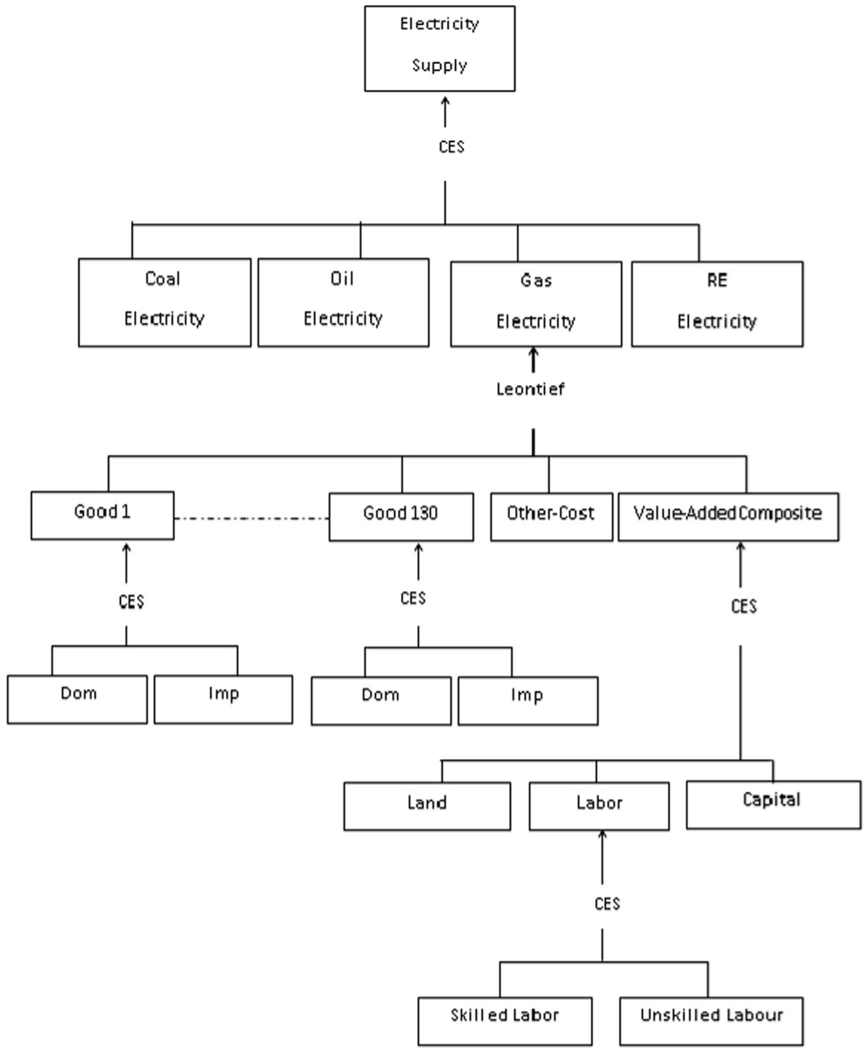

Fig. 4. Structure of production for electricity sector.
Source: author's elaboration

generation is only used by the electricity supply sector and the model differentiates between four forms of electricity generation, namely, three from conventional fossil-fuels and one based on aggregated RE for commercial electricity output. The output of the different generation sectors is the input for the electricity supply industry which then transmits and distributes it to other industries and final users.

To date, few studies have used a comprehensive quantitative model that specifically includes an extended economic model with emphasis on the electricity sector and its environmental linkages to assess the impact of FiT for Malaysia. Further, the database and model of the abovementioned studies do not address the detailed technologies in electricity generation. This study attempts to address this gap by financing RE expansion through an appropriate FiT policy complemented with a subsidy removal scheme. The production structure of the model allows substitution possibilities between different energy sources within the electricity sector.

Specifically, Fig. 4 describes the input structure of the electricity supply industry. Comparing this with nested of production for non-electricity industries shows that the production structure of the electricity supply industry differs from other industries in the way they obtain the input. The electricity supply industry is a CES aggregation of four types of generation based on the energy input used whether gas, coal, oil, or RE sources. Each generation process is assumed to produce a particular type of product (coal-electricity, gas-electricity, etc.) using relatively fixed input proportions (Leontief function). In this approach, electricity generation is allowed to shift from highly subsidized gas generation to other generation technologies (e.g., coal and renewable energy electricity). As such, the CES production function is employed to form commercial electricity.

3.1.4. Household demand structure

Based on the input-output framework, representative household demand is captured in the model in line with the final demand column. In other words, a representative household maximizes its utility function in respect to budget constraints. The changes in household demand demonstrate household welfare through equivalent variation (EV) measurements. Specifically, similar to intermediate and investment demand behaviours, households aggregate source-specific commodities using an Armington and CES function and, subsequently, Klein–Rubin forms the household utility function for consuming source-aggregated commodities.

In the household consumption block, the model adopts the demand function of the linear expenditure system (LES) which is derived from the maximization of a Klein-Rubin [38] utility function. An important feature of this functional form is that it distinguishes between necessary and luxury demands associated with each good. Similar to the intermediate

demand part, choices of the household sector are between domestic and imported commodities, and modeled by a CES functional form.

3.1.5. Export structure

Following Horridge [34], the model for this study distinguishes between two different groups of exports, namely individual and collective export commodities. The former includes all the main export commodities, and it is assumed that their demand equations are downward sloping and a function of the foreign price elasticity of their demand. In contrast to individual export demand equations, the foreign demand for collective export commodities is inversely related to the prices of all the collective export commodities. Typical inclusions are service commodities where export volumes do not necessarily depend on the corresponding price of the commodity. Therefore, a “collective exports” commodity is created through a Leontief technology.

3.1.6. Welfare measurement

As is common in CGE literature, the Hicksian equivalent variation (EV) index is adopted from Horridge [39] in this study to measure changes in economic welfare caused by changes in the prices of commodities. In this study, the EV resulting from a subsidy reduction policy and a FiT scheme is referred to as the amount of money that a household would be willing to pay to avoid the price rise consequence of a policy. As noted, improvements (losses) in welfare are denoted as positive (negative) EV, respectively.

3.2. Database

3.2.1. Malaysia's input-output table

The main source of data forming the basis of the model in this study is the 2010 Malaysia input-output table published by the Department of Statistics [32].[13] The table distinguishes between 124 different commodities and 124 different industries. In addition, final demand includes private households, government, exports, investments, and stock purchases. As is often the case, the structure of the published data is not in the required format of a CGE database and requires transforming the former into the format of the model. The model of this study requires a database with separate matrices for basic, tax, and margin flows for both domestic and imported sources to domestic and foreign users, as well as for the primary factors of production for the latest possible year.

3.2.2. Gross value added

The CGE model in this study distinguishes three types of factors of production: labor, capital, and land. Consequently, different justifications are needed to prepare the primary factor flows (gross value added). The original tables only include income accruing to employees and exclude non-employee income. The adjusted employee compensation factor is based on the method used by Gollin [40]. Further, as there are no values for land rentals, it is necessary to allocate some part of the gross operating surplus to land-using industries to construct a land-use matrix. This means that before adjustments, the values of compensation of employees are underestimated while that of capital rentals is overestimated.

[13] The benchmark data used in the database refers to 2010 but was published in 2015. However, the authors believe that the tables are suitable for use as a benchmark since: i) the input output table is published in the form of 12 detailed tax and margin Use and Make matrices; ii) the share of important sectors have not changed substantially; iii) the analysis and simulation results are presented in percentage and not ordinary changes and, as such, the absolute values will not alter the results; iv) the sensitivity analysis section tested the sensitivity of results to the database in some ways and shows that the results are not sensitive to absolute values; and v) Malaysia's economic structure has not changed substantially since 2010.

3.2.3. Energy sectors’ extensions

As the official input-output tables for the energy sectors consist of only three energy commodities it is necessary to expand some of them. As a first step, the crude oil-natural gas and electricity-distributed gas industries are disaggregated into four new sectors using data from the National Energy Balance [10] and Energy Commission [41]. This is a complicated process as in Malaysia's Domestic Use tables natural gas inputs to the electricity industry are included in the petroleum sector and are thus supplied via petroleum and coal products [42]. As such, in the second step, other assumptions would require that these flows be redefined. Therefore, for the electricity industry, the input value of petroleum products and coal has been revised correspondingly. That means that the sum of the three input values corresponds to the previous sum of the two values, but the composition between them has changed according to the fossil-fuel price and quantity ratios from Othman [43] and the data from National Energy Balance [10], respectively. CO_2 emissions from different fossil-fuel generation types are calculated based on the method used in Yahoo and Othman [44].

3.2.4. Disaggregation of the electricity sector

Data from the Malaysia National Energy Balance shows that electricity products are generated using different fuels, namely coal, which is polluting, and those using cleaner fuels such as gas and biomass. Different policies in the energy sector seek to skew the power generation structure towards greener technologies. Accordingly, in exploring the impacts of alternative scenarios in the electricity sector, it is necessary to disaggregate the electricity industry in the model and database into different technologies namely coal, oil, natural gas, and renewable sources. Since official sources do not provide data on material inputs for the generation sectors, this paper follows the methodology presented by Gay and Proops [45] and Proops et al. [46]. To perform this disaggregation it is assumed that: i) fossil fuel generation is fed entirely by fossil fuel inputs, ii) all other intermediate inputs to the electricity sector are disaggregated into four generation sectors proportionally based on the electricity generation output for each generation type, iii) the output of the electricity generation sectors is only used as an intermediate input by the electricity supply sector, and iv) other sectors and final demanders purchase the output produced by the electricity supply industry [47]. Finally, a 130 by 130-sector database is constructed and used in this paper to prepare four different policy scenarios in line with the objectives.

3.3. Simulation scenarios

The simulations are performed under several scenarios that are fundamentally divided into four categories (Table 2). The choice of simulations is driven by current real and prospective issues in the Malaysian electricity sector. The choice of the first scenario is based on the fact that the Malaysian government has taken the necessary steps to reform energy subsidies in the country. This is noted in the Tenth Malaysia Plan [48] which proposes that price controls and subsidies on natural gas be gradually rationalized to achieve market pricing by the end of the plan period. Under the plan, the cost of subsidized energy commodities to the power sector needs to be regularly adjusted by a fixed percentage every six months, including the consumption subsidies on natural gas in the electricity sector [49].

More specifically, based on the 2015 gas price revision by the government aimed at trimming the subsidy budget, TNB raised the cost of natural gas supplied to the power sector by 10% from MYR13.70 ($3.5) per MMBtu to MYR15.20 ($3.90) per MMBtu [50].[14] In 2015, the power producer's natural gas price was capped at MYR15.20 ($3.90)

[14] 1 $ equals 3.9 MYR in 2015.

per MMBtu through subsidies while the unsubsidized market price was about MYR46.04 ($11.8) per MMBtu. As such, the power sector enjoyed a price subsidy of about 67%.[15] Thus, to address the impact of the reduction in gas subsidies on market electricity production, prices, and input use, scenarios I, II, and IV simulate the 10% reduction in gas subsidies.[16] In scenario II, a compensation plan is assumed to first deal with the substitution effect and, indeed, observes the natural revenue assumptions from the modeling aspect. Such offsetting policy involves the savings from the gas subsidy reform being redistributed to the electricity sector in terms of a renewable energy electricity production subsidy.

The reason for conducting scenario III is to strategize on the development of RE in Malaysia. The government's main objective is to increase the proportion of electricity generated from RE sources to 5.5% of the total fuel mix [48]. Towards this end, the government introduced the Feed-in-Tariff (FiT) under the National Renewable Energy Policy and Action Plan (NREPAP). This is implemented via a mechanism where electricity users contribute an additional 1% of their total electricity bill to the RE fund [49]. It should be noted that this rate has been increased gradually and is now 1.6%. Accordingly, the third scenario seeks to simulate the effects of the imposition of a FiT policy by raising the electricity tax rate for all users by 1.6%.[17] Finally, in the last scenario, reforming the gas subsidies and transferring the revenues to the RE fund will complement the FiT policy in Malaysia as a means to accelerate the growth rate of RE electricity production.

To close the model and make an assumption on how the economy will respond to the natural gas subsidy reform policy, a short run closure is assumed in all scenarios. [18] Under the short-run simulations, which implicitly assume that the time frame does not allow for the installation of new units of capital to reflect technology improvements, capital stock is fixed and immobile between industries. Real wages in the labor market are also fixed while aggregate employment varies. Therefore, factor prices clear the market for them. Further, since a common feature of CGE models is that only relative prices matter and that all other nominal price variables change relative to changes in one exogenous price variable, the nominal exchange rate is chosen as the numeraire in four simulations in this paper.

It should be noted that the model and database of the paper extends the original model in different blocks as presented in the Appendix A (see Table A1 to A.4 for more details). Specifically, the model and database is extended with: CO_2 emission extensions (adapted from Adams et al. [20]); electricity disaggregation pattern; differentiating production structures between electricity and non-electricity sectors; designing a FiT mechanism; and subsidy removal scheme for capturing the real situation of Malaysia's economy (i.e., not making simplified assumptions for the subsidy rate). Further, the model's equations are written in percentage change form and solved by the GEMPACK [50] commercial software package (for more details about software see Horridge [34]).

4. Empirical results

4.1. Economic perspective

The main macroeconomic and welfare impacts of each scenario are shown in Table 3↓. The simulation results indicate that a 10% reduction in gas subsidies from the electricity generation sector will result in negative macroeconomic effects on the Malaysian economy (where real GDP and employment decrease by 0.04% and 0.1%, respectively) and the electricity sector (output from electricity supply decreases by 0.28%), when the revenue neutrality assumption is excluded. It means that revenues collected from the subsidy removal are not recycled into the economy in any form such as lowering labor income tax or lump sum payment to households. In other words, it only increases government revenues [51]. In line with the short-run closure assumptions, with industry capital stocks fixed, the changes in GDP from the income side is from the change in employment (−0.03) and indirect tax accounts (−0.01). As a result of the higher industrial nominal wage costs of labor caused by the increase in consumer prices, employment falls by 0.03%,[19] indirect tax contributions decrease by 0.01%, and real GDP declines by 0.04%. On the expenditure side, since both total investment and government expenditures are held fixed, the − 0.04% change in real GDP is attributed to the 0.02% decrease in both household demand and balance of trade. The application of gas subsidy reduction rates in the simulations under the first scenario indicates a deterioration in Malaysia's balance of trade, real GDP, and aggregate employment under this policy. Findings show that household welfare and consumption are negatively affected (by MYR −146.3 and −0.04, respectively) as the government does not redistribute the savings from this policy to the household sector. Overall, although a subsidy reduction will have negative effects on consumers, the results show that net gains to society were not negligible.

Comparing the results of a subsidy reduction with that of a subsidy reduction and revenue recycling shows that GDP still declines but by a lower extent (0.004% vs. 0.04%).[20] This lower decrease is expected since subsidy reduction revenues are recycled back into the economic system through the RE electricity production subsidy, and such redistribution offsets some of the reductions in GDP components from both the expenditure and income sides. Some interesting findings can be

[15] In 2010, the gas price was capped at MYR10.70 ($3.32) per MMBtu while the unsubsidized market price was MYR40.70 ($12.64) per MMBtu [6]. As such, the power sector enjoyed a price subsidy of about 73.7%. This formula shows the calculation of the subsidy for natural gas using the subsidy rate of 73.7% and basic flows data $P_{Gas*}Q_{GAS.}$ $Subsidy_{NaturalGas}$ = Subsidy $_{Rate}$ * Flows Value $_{(Basic\ Price,\ MYR\ Million)}$ =0.737*6650.95. Flows value refers to the amount of subsidy in the database of the model. Then multiplying the subsidy rate into total subsidy returns the exact value of the subsidy (natural gas Subsidy = 4855.19). Further, the shocked rate for subsidy reduction is calculated by: Percentage change in power of subsidy = $\frac{T_1 - T_0}{T_0}$*100.

[16] It should be emphasized that in the constructed database the 74% subsidy rate is observed compared to other subsidy reform studies in the literature. In other words, in the subsidy reduction scenarios, the corresponding variable on the subsidy for natural gas used in the electricity sector (negative value) has been shocked exogenously rather than imposing tax on electricity to show subsidy reform.

[17] This scenario highlights the shortcoming in using a tax as a proxy for subsidy reforms when the subsidy is explicitly modeled and included in the database.

[18] In the CGE literature, the determination of which variables are to be exogenous and which endogenous are referred to as closing the model. Further, in the closure of the model, exogenous variables have been determined. Since the model of paper is calibrated by an input-output database, variables in labor and capital markets need to be specified as exogenous or endogenous. Therefore, for each variable which is determined exogenously (endogenously), there is a corresponding variable which should be identified endogenously (exogenously) to make the simulation environment close enough to the real economy. Indeed, making assumptions for converging a model with many variables and simultaneous equations in a typical CGE framework is inevitable in Walrasian general equilibrium (GE) models in the literature of GE modeling.

[19] This reduction is due to the decline in employment in GDP decomposition from the income side while the aggregate employment reported in Table 3 (−0.1%) is a weighted average of the percentage change in employment by each industry. Thus, these numbers should not be equal.

[20] Since the value of total natural gas subsidy relative to total GDP is small in 2010, reducing the subsidy by 10% will not substantially change the endogenous variables. The idea for the value of subsidy reduction is based on real economic perspectives. Further, the percentage change of subsidy cut is equal across scenarios and the complementary policy changes between different simulations. Indeed, as shown in Table 4 for sensitivity analysis, by assuming a higher rate for subsidy reduction, the macroeconomic variables changed with larger percentages. This shows the importance of the shock value in the simulations.

Table 2
Scenarios for static CGE model simulation.

Project	Explanation
Scenario I	Phasing out the subsidy for natural gas used in power generation sector by 10%.[a]
Scenario II	Phasing out the subsidy for natural gas used in power generation sector by 10%. Revenues generated used to generate electricity from renewable sources.
Scenario III	Implementation of FiT policy through imposing consumer tax for electricity consumed by all agents (producers plus household sector).[b] Revenues generated used to generate electricity from renewable sources.
Scenario IV	Phasing out the subsidy for natural gas used in power generation sector by 10% accompanied with the implementation of FiT policy on all agents. Revenues generated used to generate electricity from renewable sources.

[a] It should be noted that based on the subsidy rationalization program of the Ministry of Energy Green Technology and Water, in all four scenarios, the subsidy for petroleum products used in power generation is also removed, although petroleum products contributed to 6% of total generation mix.
[b] Following the government FiT policy, a tax rate equal to 1.6% is uniformly imposed.

Table 3
Results of key macroeconomic variables.

Variables (volume)	Scenario I	Scenario II	Scenario III	Scenario IV
Real GDP	− 0.04	− 0.004	− 0.007	− 0.008
Real household consumption	− 0.04	− 0.005	− 0.01	− 0.01
Aggregate employment	− 0.10	− 0.01	− 0.01	− 0.004
Export volume	− 0.05	− 0.01	− 0.01	− 0.02
Import volume	− 0.03	− 0.01	− 0.01	− 0.02
Consumer price index (CPI)	0.04	0.01	0.01	0.02
Terms of trade	0.01	0.002	0.002	0.004
Aggregate payment to labor	− 0.05	0.001	− 0.001	0.02
Aggregate payment to capital	− 0.10	0.05	0.04	0.16
Aggregate payment to land	− 0.03	− 0.01	− 0.01	− 0.02
Equivalent Variation (MYR Million)	− 146.33	− 18.41	− 36.61	− 43.49

Except otherwise indicated, figures are percentage changes from base-run.

observed from the second scenario in which the output from gas-based electricity subsidy is reduced by 0.7% but when the revenue recycling plan is included by subsidizing electricity from RE sources, the RE output increased by 6.9%. First, comparing the results between scenarios I and II shows that the compensation plan seems to somewhat offset the negative impacts of the subsidy removal. In terms of household welfare, MYR18.41 reduction in EV confirms that the negative effects of gas subsidy removal is offset by RE production when electricity supply output increases by 0.03.

This confirms that by recycling the subsidy reduction revenue to RE electricity production, the combination of input mix in the electricity supply industry changes due to the movement of factors of production away from thermal to RE generation. Thus renewable electricity output grows significantly leading to an increase in the demand for capital and, consequently, payments to this factor. Another key finding under this scenario is that when revenue from a subsidy reduction policy is reallocated for RE electricity generation, the negative macroeconomic costs from the subsidy reform is outweighed by the positive gain from the revenue recycling plan.

Under the third scenario this research examined the imposition of a FiT scheme in the absence of subsidy reduction. Simulation results indicate that FiT alone cannot be considered an effective policy for the promotion of RE technology compared to the second scenario. This is because financing RE electricity production by passing the cost to final electricity consumers such as households not only fails to stimulate RE electricity production more when compared to the second scenario, it also creates larger negative effects on macroeconomic variables when GDP decreases by 0.007%. This confirms that the positive effect of RE electricity production under FiT in terms of a household tax is outweighed by the negative effects resulting from the price inducement outcomes which negatively affect total demand. In addition, household welfare loss from financing RE electricity production in scenario III is much higher than in scenario II (MYR36.6 Vs. MYR18.41).

The findings from simultaneously implementing a FiT mechanism with a subsidy reduction and a revenue recycling plan show that the combined policy will expand the range of feasible FiT financing substantially (RE electricity increases by 12.7%). From the macroeconomic viewpoint, this policy produces negligible negative macroeconomic effects and significantly alters RE output. The implementation of both policies will result in real GDP decreasing by 0.008%, which is marginally higher than a FiT-only scenario (−0.007%). As can be seen, financing RE-electricity production from two sources in this simulation leads to a relatively lower reduction in the aggregate employment index (−0.004) due to higher employment growth in the RE electricity sector (the negative growth rate in employment from fossil-fuel based electricity sectors is outweighed by the positive percentage change in employment in RE-based electricity sector). This higher employment leads to a lower decline in the aggregate employment index, in line with the share of RE electricity production in the generation mix. Another interesting result is that the returns to capital are higher (0.16), reflecting the increase in its price. This outcome has its origins in the larger increase in demand for capital due to the greater expansion in RE electricity output under this scenario. The simulation results show that since the government has targeted to raise the portion of electricity generated from RE sources to 5.5%, the FiT may be Malaysia's best option to see substantial development based on such a resource for the electricity sector.

Comparing the results of scenario IV and those in I and II in terms of the impact on GDP growth reveal some interesting results. When revenues from subsidy removal are not rechanneled back into the economy, GDP, as expected, decreased by as much as 0.04% in scenario I compared with 0.008% in scenario IV. This is because the subsidy removal policy contracts economic activities without altering production for substituted energies such as RE. However, the bigger decline in GDP growth in scenario IV compared to scenario II is a compositional effect. In other words, when FiT policy is implemented to further increase financing for RE production, its negative effects on household disposable income and consumption is larger than the positive effect of a larger increase in RE production. The main reason for this outcome is that the linkages between household income and the supply of primary factors as labor are not modeled in this paper. In other words, when a FiT policy is taken into the account with subsidy removal, it results in higher RE production and larger employment growth. However, if the effects are not transferred to households via an increase in household income (and consumption), then it is expected that GDP will be more negatively impacted in scenario IV compared to scenario II but have higher positive effects when compared to scenario I.

Besides the macroeconomic impacts, changes in sectoral outputs are quite significant for the fuel-based electricity industries (see Fig. 5). It is evident from the simulation results that the electricity-gas industry will suffer the most under a gas subsidy reduction as it relies mostly on natural gas as an input in the production process (of about 53%). The output of the industry will decrease by 0.51% as a result of the higher cost of gas-powered generation following the subsidy reduction. This result is expected as a response to the shock variable. The electricity-supply industry also records relatively high negative growth (0.28%).

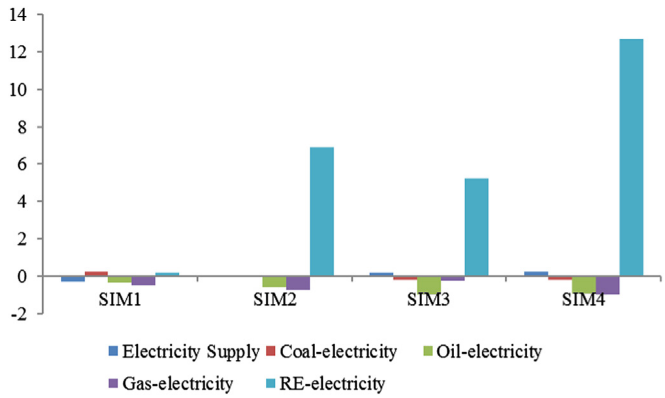

Fig. 5. Output of electricity industries (%).
Source: author's calculations

This is due firstly to a reduction in electricity demand in response to an increase in the price of electricity to final consumers and, second, to the increase in output prices as a result of an increase in its production cost. The latter stems largely from gas generation's high share in the electricity supply industry. The chief output gainer is coal electricity at 0.24%, followed by RE electricity at 0.21% and is mainly due to the substitution effects in the electricity industry.[21] The substitution of coal for natural gas is due to the relatively higher cost of electricity generation by burning gas when its subsidy is reduced.

Reducing the subsidy for natural gas consumed by the electricity sector and financing electricity production from RE sources will, in turn, encourage producers to step up electricity production from RE sources thus significantly increasing its output by about 6.92%. Alternatively, the output of the gas and oil electricity industry is negatively affected when the subsidy is reduced, declining by 0.7% and 0.6% respectively. Compared with the first scenario, the fall in their outputs is more drastic since the increase in RE electricity output by producers receiving the production subsidy is more pronounced. The growth in the output of electricity from coal generation is less under second scenario compared to the first scenario as the electricity supply sector in general benefits from the increase in RE electricity production and therefore, there is less substitution to other sources of production such as coal. Indeed, the direct effect of a decrease in the price of RE generation inputs is a decrease in the use of substitutable inputs. Since the electricity output from all generators is only used by the electricity supply sector, the distribution of electricity increases by 0.03% following the significant rise in RE generation.

Overall, the simulation results show that when a FiT policy is accompanied by natural gas subsidy reforms, the increase in RE electricity production is more pronounced while fossil-fuel based electricity industries experience bigger reductions in their output. The increased RE electricity output is mainly caused by an increase in demand for it. This is the outcome from the larger reduction in its price due to the higher subsidy received since its production is financed through two sources. Finally, the imposition of a FiT policy under the subsidy program shows that more RE electricity is generated compared to when any FiT and subsidy reduction policy is implemented separately.

Fig. 6 shows percentage change in demand for output from different electricity generators. This result is explained by the substitution effect. The simulation results from scenario I show that due to the changes in the structure of electricity industry in favor of other sources of energy for producing electricity, the demand of the electricity supply industry for coal and RE generation increases significantly. Demand for the output from these sectors rises by 0.10% and 0.09% respectively. Higher prices for gas-based electricity products will decrease the demand for gas by the electricity supply industry by 0.61%. This is consistent with the theory since relative changes in demand for inputs are related to their share and elasticity. In other words, a higher share of input and its own elasticity will result in a relatively greater change in demand for that input.

[21] The reduction of oil generation output in this simulation is due to the removal of the petroleum product subsidy in oil-based electricity generation in line with petroleum subsidy reform policy which is implemented in all simulations to better reflect the real overall economic situation.

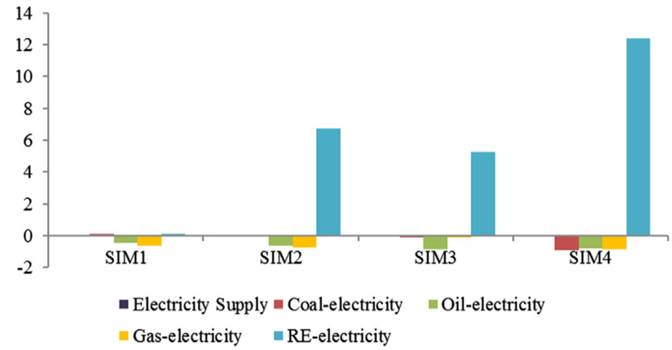

Fig. 6. Demand of output from electricity generators (%).
Source: author's calculations

The demand for natural gas for gas electricity generation declines by 0.72% unlike the lower increase in the price of natural gas in scenario II compared with the first scenario. This decrease is mainly due to the fall in electricity demand for gas-based generation (price effect) and a significant increase in the use of RE generation as a substitutable input (substitution effect). Since the revenues collected from the subsidy reduction finances RE electricity production, the increase in the price of electricity is lower compared to the results in scenario I. Subsequently, consumers will reduce their demand for commercial electricity with a lower rate.

The results from scenario III indicate that the demand for different fossil-fuel-based generators decreases while projections show an increase in demand for RE based generation. In scenario IV, the high subsidy allocated for the production of RE electricity production reduces the price of this commodity more as well as leads to the highest increase in demand. On the other side, since these commodities are only demanded by the commercial electricity supply industry and due to the substitution effect, the demand for fossil-fuel based electricity commodities decrease.

4.2. Environmental perspective

Fig. 7 compares the results for CO_2 emissions by input type used by different generators among four scenarios. It clearly shows that the reduction of the gas subsidy to the power sector lowers electricity consumption and leads to lower total CO_2 emissions from the power generation sector under all scenarios. In addition, comparisons between different scenarios highlight that reforming the gas subsidy by changing the fuel mix implies environmental changes in the form of CO_2 emission trade-offs among different fossil-fuel types. In other words, gas and RE sources are the most environmentally sound options with the latter producing zero emissions. Coincidently, switching to coal would imply that more emissions would be produced, increasing by 0.1% as Fig. 7 shows. However, in the first scenario, the policy-induced fuel mix would result in a higher reduction in total CO_2 emissions. Simply put, while the gas subsidy reduction policy would make Malaysia less dependent on gas, emissions from gas will decline. At the same time, due to the substitution effect, emissions from coal will increase thereby counteracting lower emissions from gas and result in an overall pollution decrease of 0.19%.[22] Hence, switching to renewable energy would

[22] This is in line with the contribution of each fuel type in total emissions.

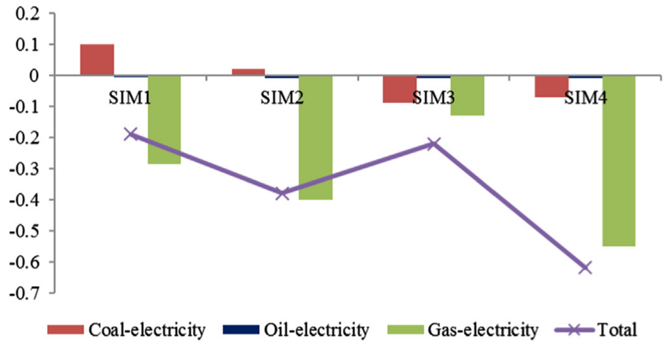

Fig. 7. CO2 emissions change by fossil-fuel generation types (%).
Source: author's calculations

reduce the dependence of Malaysia's power sector on coal for producing electricity and this would help address the issue of emissions.

The simulation results from scenario II indicate that a subsidy reduction policy coupled with a reallocation of income for the RE generation reduces CO_2 emission more due to the movement of factors of production away from thermal to RE generation. It is clear that CO_2 emissions reduction is larger when the increase in electricity from RE sources is more pronounced as in this scenario. Total CO_2 emission cuts increase from 0.19% in the subsidy-only reduction scenario to 0.38% in scenario II. The increase in CO_2 emissions from coal generators is due to the substitution effect and the increase in demand for the output from this industry. The higher reduction of CO_2 emissions from scenario III (FiT policy) shows the increase in the share of electricity by RE sources when high-carbon fossil fuels technologies such as coal are partly replaced by carbon-free and renewable power generation methods. The simulation results show that changes in the production structure of the electricity sector due to the subsidy reform policy reduces overall CO_2 emissions by about 0.22%. The contribution of each type of fossil fuel generation indicates that CO_2 emissions are reduced the most by gas-based generation followed by coal and oil based technologies.

The figure clearly confirms the results of the increase in RE electricity production when a production subsidy is financed from two sources in scenario IV. In other words, total CO_2 emissions from the electricity sector are reduced substantially compared to other scenarios. This is due to the substitution effect of fossil- to RE-based electricity generation and to the expansion in RE production. The high overall reduction in emissions is due to the modification in the production structure of the electricity sector that results in more RE electricity being produced. Total CO_2 emissions from the electricity sector decrease by 0.62% due mainly to the reduction in emissions from gas fired and coal based generators.

4.3. Sensitivity analysis

In terms of sensitivity analysis on the quantitative results three additional simulations were run in the paper. As shown in Table 4, the results are based on a 25%, 50%, and 100% (full) natural gas subsidy removal. In general, the increase in percentage of the subsidy removal value leads to broader economy-wide effects. For example, when the subsidy reduction is larger, the increase in government revenues can be applied to produce RE within the economy.

Overall, the FiT policy modifies the electricity sector's production structure where fuels that are less carbon intensive are used to produce electricity and there is higher dependence on carbon-free energy sources. The shift occurs when the contribution of coal as a high-carbon fossil-fuel power generation technology decreases while that from renewable resources increases significantly.

Table 4
Results of sensitivity analysis for scenario I.

Variables (volume)	Subsidy reduction			
	10%	25%	50%	100%
Real GDP	− 0.04	− 0.08	− 0.17	− 0.36
Real household consumption	− 0.04	− 0.09	− 0.18	− 0.37
Aggregate employment	− 0.10	− 0.22	− 0.44	− 0.9
Export volume	− 0.05	− 0.11	− 0.23	− 0.48
Import volume	− 0.03	− 0.07	− 0.15	− 0.32
Consumer price index (CPI)	0.04	0.09	0.19	0.4
Terms of trade	0.01	0.03	0.06	0.13
Aggregate payment to labor	− 0.05	− 0.12	− 0.25	− 0.5
Aggregate payment to capital	− 0.10	− 0.23	− 0.44	− 0.85
Aggregate payment to land	− 0.03	− 0.06	− 0.12	− 0.26
Equivalent Variation (MYR Million)	− 146.33	− 332.3	− 680.1	− 1441.8
Revenues (MYR Million)	554.8	1255	2482.5	4848.4

Except otherwise indicated, figures are percentage changes from base-run.

5. Conclusion and policy implications

Electricity is one of the major factors of production and a basic item in the household purchasing basket. A change in its price affects its production structure as well as household consumption patterns and welfare. Natural gas subsidy rationalization in the power generation sector is an effective means for securing long term economic development and addressing environmental issues. In addition, achieving stable economic growth and an affordable cost of living ensures economic stability and income equality. The Malaysian government has reduced the subsidy on natural gas used by the power generation sector as a means to address budgetary and over-consumption concerns and is promoting the production of electricity using RE sources through the FiT mechanism. To evaluate the economy-wide and sectoral impacts of these measures, this paper applied a CGE model based on a database constructed from the Malaysian input-output tables. Four different scenarios over the short-term were explored.

Overall, the simulation results suggest that any gas-based electricity subsidy reform will result in negative macroeconomic effects on the Malaysian economy and the electricity sector when the revenue neutrality assumption is excluded. The application of the gas subsidy reduction under the subsidy removal only scenario (I) indicates a deterioration in Malaysia's balance of trade, real GDP, and aggregate employment. Findings show that household welfare and consumption are negatively affected as the government does not redistribute the savings from this policy to it. The reduction in the subsidy for gas-based electricity production would benefit the coal, oil, and RE electricity generation sectors and decrease output in the gas sector due to its higher production costs. The demand for gas by the electricity supply industry will decrease significantly thereby substantially reducing carbon emissions from the gas sector and increase emissions from its substitute coal sector.

The findings from simultaneously implementing a FiT mechanism with a subsidy reduction and a revenue recycling plan in the last scenario show that the combined policy will substantially expand the range of feasible FiT financing options. From the macroeconomic viewpoint, this policy induces negligible negative effects and significantly alters RE output while CO_2 emissions decrease substantially. The higher growth in employment in the RE electricity sector leads to a marginal reduction in the aggregate employment index due to the high RE electricity production in the generation mix. Another interesting result is that the returns to capital are higher, reflecting the increase in its price. This outcome has its origins in the higher increase in demand for capital due to the greater expansion in RE electricity output under scenario IV.

In sum, this research shows that the economic cost of the implementation of a subsidy depends on the design used for recycling

revenues collected from the subsidy reduction such as channeling them for RE electricity generation through a production subsidy. It is also found that any subsidy removal that is accompanied by a FiT mechanism in the power sector would not necessarily produce negative impacts on the economy when different measures are included in the energy policy decision making process. These measures are social welfare needs, carbon dioxide emissions from the power sector, and enhancing the share of RE energy in the total energy mix. This implies that in the context of a developing country like Malaysia, it is extremely important to have a policy that transforms the energy structure of the economy towards reducing CO_2 emissions. These adjustments revolve around an increase in the price of an essential energy type, and since Malaysia is at the transitional stage where social development and stability are critical for economic growth, any adverse impacts on variables such as GDP and employment from the subsidy reforms will need to be seriously considered.

In general, comparing total benefits (lower contraction in GDP growth, welfare measurement, employment and other macroeconomic variables together with higher cuts in total CO2 emissions and higher increase in RE production) with total costs of the subsidy removal and FiT policies shows that scenario IV is a more feasible option compared to scenario II. In addition, if RE production is to be financed through revenues earned from subsidy reduction and FiT policies, the total benefits will outweigh the total costs.

In terms of policy implications, it can be concluded that a subsidy reduction and FiT mechanism complemented each other and that a combination of the two policies is the most effective in promoting RE electricity production, preserving fossil-fuel resources, and increasing social welfare by taking into account environmental benefits as well as economic and social impacts. The findings from this paper highlight that the Malaysian government can achieve the RE electricity production target of 5.5% by simultaneously implementing a FiT mechanism and reforming the gas subsidy mechanism while reallocating revenues thus earned for RE production. However, the simulation outcomes show that the 1.6% currently added to the electricity bill is clearly inadequate to enable the RE fund to develop RE power, and reforming gas subsidies and transferring some of the revenues to the fund will complement the FiT policy in Malaysia as a means to accelerate the growth of RE electricity production.

Although RE expansion through subsidy removal and FiT mechanism is considered as one of the feasible options for Malaysia, however, income distribution concerns (providing low electricity prices for low income households) and the abundance of biomass, solar and biogas/waste resources are other non-economic barriers may be present to prevent the use of the proposed economic incentives.

Acknowledgments

The authors would like to express their sincere appreciation to the Editor-in-Chief and anonymous referees for their helpful comments and suggestions, which tremendously improved the quality of the paper.

Appendix A

See Tables A1–A4

Table A1
Definitions of sets in equations.

Label	Description
c	Set of 130 commodities
s	Set of sources: domestic and imported
i	Set of 130 industries
f	Set of fossil fuel based generators
occ	Set of labor classes: skilled and unskilled

Table A2
Elasticities of substitution in consumption, trade and production.

Label	Description
σ_{lab_i}	Elasticity of substitution between labor occupation types
$\sigma_{primary_i}$	Elasticity of substitution between capital, labor and land
σ_{mat_c}	Elasticity of substitution between domestic and imported materials
σ_{Export_c}	Elasticity of substitution between exportable commodities
$SHHLUX_c$	Marginal budget share of commodity c
$LUXSHARE_c$	Share of supernumerary expenditure on commodity c in total expenditure on c

Table A3
Variables.

Label	Description
$SUB - 1$	Ad valorem rate of subsidy
A	Technological coefficients
$SUBREV_{c,s,i}$	Subsidy revenue (the revenue collected from subsidy reduction)
$BAS_{c,s,i}$	Subsidy base
$delsub$	Change in subsidy rate in green energy production

(*continued on next page*)

Table A3 (*continued*)

Label	Description
$delresub$	Change in green energy production
$COST_i$	Total cost of industry i in level
$x\cos t_i$	Percentage change in demand for total cost in industry i
$p\cos t_i$	Percentage change in price for total cost in industry i
$delsubrev$	Change in revenue raised from a subsidy reduction
$fresub$	Percentage change in green energy subsidy rate
$PRTAX_{rate}$	Production tax rate
$CO2_{f,s,i}$	CO_2 emissions by fuel, source and generator type
co_2tot	Total CO_2 emissions
$XLAB_{i,occ}$	Labor demand by industry i and occupation type
$XLABOCC_i$	Occupation-aggregated labor input for industry i
$XPRIMARY_i$	Aggregated capital, labor and land demand by industry i
$xcapital_i$	Demand for capital by industry i
$XSOURCE_{c,i}$	Source aggregated demand by commodity c by industry i
$xsource_{c,i}$	Demand for source aggregated commodity c by industry i
$psource_{c,i}$	Price of source aggregated commodity c by industry i
$xtotinv_i$	Sectoral investment output
$xsub_c$	Household subsistence demand for good c
$xlux_c$	Household luxury demand for good c
$XEXPORT_c$	Export demand for good c
$PEXPORT_c$	Domestic price for exportable good c
$OSHIFT_c$	Horizontal shifts in the individual export demand schedules
$PSHIFT_c$	vertical shifts in the individual export demand schedules
$TARREV_c$	Ordinary changes in tariff revenue from commodity c
$EXRATE$	Nominal exchange rate
CIF_c	C.I.F foreign currency value of imported good c

Table A4
Model equations[a].

Subsidy rate and revenue block:

$$SUB-1=\frac{SUBREV_{c,s,i}}{BAS_{c,s,i}}$$

$$\Delta SUBREV_{c,s,i}=\Delta BAS_{c,s,i}*(sub-1)+\Delta SUB*BAS_{c,s,i}$$

$$delsub=COST_i*[delresub+0.01*RESUB*[x\cos t_i+p\cos t_i]]$$

$$delsub=-delsubrev+fresub$$

$$delPRTAX_i=PRTAX_{rate_i}*delCOST_i+COST_i*delPRTAX_{rate_i}$$

$$delPRTAX_{rate_i}=delresub$$

Environmental pollution block:

$$CO_2TOT=\sum\nolimits_{f,s,i}(CO2_{f,s,i})$$

$$100*\Delta CO_2TOT=CO_2TOT*co_2tot$$

Industry block:

Labor Composite:

$$XLABOCC_i=CES[XLAB_{i,occ}]$$
$$xlab_{i,occ}=xlabocc_i-\sigma_{lab_i}*(plab_{i,occ}-plabocc_i)$$

Demand for primary factors:

$$XPRIMARY_i=CES\left[\frac{XLABOCC_i}{ALABOCC_i},\frac{XCAPITAL_i}{ACAPITAL_i},\frac{XLAND_i}{ALAND_i}\right]$$
$$xcapital_i-acapital_i=xprimary_i-\sigma_{primary_i}*(pcapital_i+acapital_i-pprimary_i)$$

Demand for source specific materials:

$$XSOURCE_{c,i}=CES\left[\frac{XMAT_{c,s,i}}{AMAT_{c,s,i}}\right]$$
$$xmat_{c,s,i}-amat_{c,s,i}=xsource_{c,i}-\sigma_{mat_c}*(pmat_{c,s,i}+amat_{c,s,i}-psource_{c,i})$$

(continued on next page)

Table A4 (*continued*)

Investment block:

$$XINV_i = \frac{1}{AINV_i} * MIN\left[\frac{XINVSRC_{c,i}}{AINVSRC_{C,I}}\right]$$

$$xinvsrc_{c,i} - (ainvsrc_{c,i} + atotinv_i) = xtotinv_i$$

Household block:

$$Utility = \frac{1}{O}\Pi\,[XHOUS_c - XHSUB_c]^{SHHLUX_c}$$

$$xhoussrc_c = LUXSHARE_c * xlux_c + [1 - LUXSHARE_c] * xsub_c$$

$$utility + q = \sum SHHLUX_c * xlux_c$$

Export block:

$$XEXPORT_c = OSHIFT_c * \left[\frac{PEXPORT_c}{EXRATE * PSHIFT_c}\right]^{\sigma EXPORT_c}$$

Tariff revenue block:

$$TARREV_c = CIF_c * EXRATE * (TARRATE_c - 1)$$

[a] The core part of model equations is adapted from Horridge [34] with the extension for substitutions between different electricity generator types and energy–primary factors. CO_2 emission extensions are adapted from Adams et al. [20]. The model equations are written in percentage change form and solved by the GEMPACK [50] commercial software package. For more details, see Horridge [34].

References

[1] Institute of Strategic and International Studies. Reforming Peninsular Malaysia's Electricity Sector: challenges and prospects. Kuala Lumpur, Malaysia: Institute of Strategic and International Studies (ISIS); 2014.

[2] Chattopadhyay D, Jha S. The impact of energy subsidies on the power sector in Southeast Asia. Electr J 2014;27(4):70–83.

[3] Birol F. World energy outlook 2010. Int Energy Agency 2010(3):1.

[4] IEA, Worlds Energy Outlook. International Energy Agency, Organisation for Economic Co-operation and Development, Paris, 2010.

[5] IEA, Worlds Energy Outlook. International Energy Agency, Organisation for Economic Co-operation and Development, Paris, 2016.

[6] Energy Commission, National Energy Balance. 2015a, Minister of Energy, Green Technology and Water Malaysia: Putrajaya, Malaysia.

[7] Energy Commission, Annual Report. 2015b, Minister of Energy, Green Technology and Water Malaysia: Putrajaya, Malaysia.

[8] PETRONAS, PETRONAS Annual Report. 2015: Petaling Jaya, Malaysia.

[9] Yahoo M, Othman J. Employing a CGE model in analysing the environmental and economy-wide impacts of CO_2 emission abatement policies in Malaysia. Sci Tot Environ 2017;584:234–43.

[10] Energy Commission, National Energy Balance. 2010b, Minister of Energy, Green Technology and Water Malaysia: Putrajaya, Malaysia.

[11] ONG H, Mahlia T, Masjuki H. A review on energy scenario and sustainable energy in Malaysia. Renew Sustain Energy Rev 2011;15(1):639–47.

[12] Chatri F., and Yahoo M. Economic analysis of gas subsidy reform and FiT mechanism in the Malaysia Electricity Sector based on the CGE Model. In: Proceedings of the 33rd USAEE/IAEE North American conference on the dynamic energy landscape, Oct 25-28, 2015. International Association for Energy Economics.

[13] Ali R, Daut I, Taib S. A review on existing and future energy sources for electrical power generation in Malaysia. Renew Sustain Energy Rev 2012;16(6):4047–55.

[14] Hao X, et al. Hydrogen production from glucose used as a model compound of biomass gasified in supercritical water. Int J Hydrog Energy 2003;28(1):55–64.

[15] Wang T, Gong Y, Jiang C. A review on promoting share of renewable energy by green-trading mechanisms in power system. Renew Sustain Energy Rev 2014;40:923–9.

[16] Ming Z, et al. Overall review of renewable energy tariff policy in China: evolution, implementation, problems and countermeasures. Renew Sustain Energy Rev 2013;25:260–71.

[17] Edalati S, et al., Solar photovoltaic power plants in five top oil-producing countries in Middle East: A case study in Iran. Renewable and Sustainable Energy Reviews, 2016.

[18] Tabatabaei SM, et al. Economic, welfare and environmental impact of feed-in tariff policy: a case study in Iran. Energy Policy 2017;102:164–9.

[19] Korsavi SS, Zomorodian ZS, Tahsildoost M. Energy and economic performance of rooftop PV panels in the hot and dry climate of Iran. J Clean Prod 2018;174:1204–14.

[20] Adams, PD, Horridge M, and Parmenter BR, MMRF-GREEN: A dynamic, multi-sectoral, multi-regional model of Australia. 2000: Monash University, Centre of Policy Studies/IMPACT Centre.

[21] Lin B, Li A. Impacts of removing fossil fuel subsidies on China: how large and how to mitigate? Energy 2012;44(1):741–9.

[22] Solaymani S, Kari F. Impacts of energy subsidy reform on the Malaysian economy and transportation sector. Energy Policy 2014;70:115–25.

[23] Yusuf AA, Djoni H, Wawan Hermawan Y. AGEFIS: applied general equilibrium for fiscal policy analysis. Bandung: Center for Economics and Development Studies, Department of Economics, Padjadjaran University; 2008.

[24] Dartanto T. Reducing fuel subsidies and the implication on fiscal balance and poverty in Indonesia: a simulation analysis. Energy Policy 2013;58:117–34.

[25] Oktaviani R, Hakim D, and Siregar S, Impact of a lower subsidy on indonesian macroeconomic performance, agricultural sector and poverty incidences: a recursive dynamic computable general equilibrium analysis. MPIA Working Paper 2007–2008; 2007.

[26] AlShehabi OH. Energy and labour reform: evidence from Iran. J Policy Model 2012;34(3):441–59.

[27] BuShehri MA, Wohlgenant MK. Measuring the welfare effects of reducing a subsidy on a commodity using micro-models: an application to Kuwait's residential demand for electricity. Energy Econ 2012;34(2):419–25.

[28] Hamid KA, Rashid ZA. Economic impacts of subsidy rationalization in Malaysia. Energy Market Integration in East Asia: Theories, Electricity Sector and Subsidies, ERIA Research Project Report. 17. 2011. p. 207–52.

[29] Energy Sector Management Assistance Programme (ESMAP), Energy Policies and the Mexican Economy. 2004: Washington, D.C. p. 78.

[30] Fuinhas JA, Marques AC, Koengkan M. Are renewable energy policies upsetting carbon dioxide emissions? The case of Latin America countries. Environ Sci Pollut Res 2017:1–11.

[31] Paramati SR, Sinha A, Dogan E. The significance of renewable energy use for economic output and environmental protection: evidence from the Next 11 developing economies. Environ Sci Pollut Res 2017:1–15.

[32] Department of Statistics, *Input-Output Tables for 2010*. 2015: Putrajaya, Malaysia.

[33] Dixon PB. Orani, a multisectoral model of the Australian economy. Vol. 142. 1982: North Holland.

[34] Horridge, M., B.R. Parmenter, and K.R. Pearson, *ORANI-G: A General Equilibrium Model of the Australian Economy.* 2003: Victoria University, Centre of Policy Studies, Australia.

[35] Adams, P.D., J.M. Horridge, and B.R. Parmenter, *MMRF-GREEN: A dynamic, multi-sectoral, multi-regional model of Australia.* 2000, Victoria University, Centre of Policy Studies/IMPACT Centre.

[36] Arrow KJ, et al. Capital-labor substitution and economic efficiency. Rev Econ Stat 1961:225–50.

[37] Armington PS. A theory of demand for products distinguished by place of production. Staff Pap 1969;16(1):159–78.

[38] Klein LR, Rubin H. A constant-utility index of the cost of living. Rev Econ Stud 1947;15(2):84–7.

[39] Horridge M, Percent change forms for the equivalent and compensating variations with the LES. Centre of Policy Studies and Impact Project, Monash University,

Australia, 2005.
[40] Gollin D. Getting income shares right. J Political Econ 2002;110(2):458–74.
[41] Energy Commission, Electricity Supply Industry in Malaysia Performance and Statistical Information. 2010a, Minister of Energy, Green Technology and Water Malaysia: Putrajaya, Malaysia.
[42] Jacobsen HK. Energy intensities and the impact of high energy prices on producing and consuming sectors in Malaysia. Environ, Dev Sustain 2009;11(1):137–60.
[43] Othman J, Jafari Y. Identification of the key sectors that produce CO_2 emissions in Malaysia: application of input–output analysis. Carbon Manag 2016;7(1–2):113–24.
[44] Yahoo M, Othman J. Carbon and energy taxation for CO_2 mitigation: a CGE model of the Malaysia. Environ, Dev Sustain 2017;19(1):239–62.
[45] Proops JL, Faber M, Wagenhals G. Reducing CO_2 emissions: a comparative input-output-study for Germany and the UK. Springer Science & Business Media; 2012.
[46] Gay PW, Proops JL. Carbon dioxide production by the UK economy: an input-output assessment. Appl Energy 1993;44(2):113–30.
[47] Cruz LM. Energy-environment-economy interactions: An input-output approach applied to the Portuguese case. In: Proceedings of the 7th biennial conference of the international society for ecological economics, Sousse, Tunisia; 2002.
[48] Economic Planning Unit, Tenth Malaysia Plan 2011–2015. 2010: Putrajaya: Prime Minister's Department.
[49] Authority SED. Handbook on the Malaysian feed-in-tariff for the promotion of renewable energy. Malaysia: Ministry of Energy, Green Technology and Water; 2011.
[50] Codsi G, Pearson KR. GEMPACK: general-purpose software for applied general equilibrium and other economic modellers. Comput Sci Econ Manag 1988;1(3):189–207.
[51] Solaymani S. Carbon and energy taxes in a small and open country. Glob J Environ Sci Manag 2017;3(1):51–62.